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THE STRUCTURE AND GROWTH OF DOMESTICATED ANIMALS.*

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THE subject announced in the programme for this evening's lecture is "The Structure and Growth of Domesticated Animals." It would take a year's course to do justice to the whole subject, and I had therefore to choose a portion of it, and especially such a part as may give you an idea of the difficulties of investigating some of the topics which are, perhaps, of the greatest importance in practical life. It is often expected that science will furnish all the information wanted at a given moment, but unfortunately science is not always ready. My object is to show that you must have knowledge before you can apply it, and that knowledge is not always to be had for the asking. There is not always that information on hand which may be needed even for the most useful purposes; and in order to allay the impatience which is sometimes manifested in respect to the want of usefulness on the part of scientific men and their ability to enter into the arena of practical life, I wish to show you how difficult it is to handle some of the subjects, and I have chosen one respecting which, of course, a farming community supposes that science can furnish all the information wanted.

* Delivered before the State Board of Agriculture at Barre, December 3d, 1872. From the Twentieth Annual Report of the Secretary of the Massachusetts Board of Agriculture. We are indebted to C. L. Flint, Esq., Secretary of the Board, for the use of the accompanying illustrations.

Concerning the anatomy of our domesticated animals there is a great deal known; enough to give a good idea of the peculiarities of the full-grown animals of the different kinds which we raise to use for various purposes. Concerning the functions of their organs, there is also a great deal known, which is of value and service to guide us in our treatment of them. Nobody expects to treat a pig as he treats a horse; and the difference in our management of two such animals is determined by what we know of their structure, by what we know of the functions or the play of their characteristic organs; but there is one topic about which the farmer would like to know more, and that is in reference to breeding; and especially such points in the process of breeding as would enable him to do certain things which would add greatly to the value of our stock. If it were known how to raise male animals in places where it is desirable to have them in larger numbers, if it were known how to raise heifers in those regions where dairy farming is largely carried on, imagine what an advantage it would be to be able to determine beforehand the sex of the animals to be bred. Unfortunately, we do not know enough to-day to guide us in that direction, and yet I have not the remotest doubt that the time is coming when we shall be able to bring forth what we want, as we have been able to produce certain peculiar modifications of the various kinds of domesticated animals to suit our purposes,—when we want beef rather than milk, when we want strength rather than delicacy of structure. Now, how shall we get at it? We have not the information. You may consult the men of science, the most learned men of the day in every part of the world, and they will say, "Upon these topics we have no satisfactory knowledge whatsoever." It is to be reached only by studying the various functions connected with the process of breeding, by studying especially the earlier stages of the growth of animals with which we are familiar, and studying them with reference to that point. Upon that topic I will make a few statements concerning the facts with which I am familiar.

It is not long since all animals were divided into two classes with reference to their breeding. Some were called oviparous—that is, egg-laying animals, which multiply by laying eggs, out of which a young animal is eventually evolved; the others were called viviparous,—such as bring forth living young, after a more or less protracted gestation; and these two classes of animals were sup-

posed to be widely different one from another, both in structure and in mode of reproduction; but less than fifty years ago, a German physiologist, Karl Ernst von Baer, one of the ablest investigators of our century, made the astounding discovery that all animals bring forth eggs that may not be distinguished from one another at a certain stage; that all our cattle, all our domesticated animals, all the beasts of the forest, as well as all the birds on earth, produce eggs similar to one another. This seems a very extraordinary statement, yet perhaps I shall be able to make you familiar with the fact, and to make you understand it as fully as you know that your hens lay eggs. But the eggs of a great many animals most useful to us, and of those about which we would like to know most, have not been studied microscopically. I have devoted a great deal of my life to similar topics, and I have never yet seen the egg of a mare; I have never yet seen the egg of a cow; I have never yet seen the egg of a pig; yet I believe that these animals bring forth eggs as much as the animals that have been investigated with reference to that point. A sufficient number of quadrupeds have been studied to leave no doubt that all quadrupeds produce eggs as well as birds, as well as all other animals, without exception. One of the ablest physiologists of our time, Professor Bischoff, of Munich, has devoted over twenty years of his life to the study of a few of these animals, and the results of his investigations are embodied in a volume of many hundreds of pages, with a large number of plates, representing the history of only four species of quadrupeds. One is the rabbit, another is the dog, a third is the guinea-pig, and the fourth a species of deer which is common in the forests of Europe,—the roebuck; and the history of these animals, as presented in this volume, covers only the very earliest period of gestation,—and mainly that portion of their history embraced during the first days of gestation, during the time when the egg of these animals is transformed into a germ which grows to be an animal like the parent. Now, unless we can have a similar history of any one of our more valuable domesticated animals, as of the horse, or of the cow, we cannot expect to know how to influence their reproduction. This is the very foundation of all knowledge in that direction. What will be necessary for that? When these investigations began they were made upon animals which could be secured at the lowest price; they were begun with the hen. Two

young German physiologists, Pander and D'Alton, under the guidance of Professor Döllinger, began that study, and, in order to ascertain how the chick is formed,—not how the chick grows in the egg, but how it is formed during the first hours after the sitting of the hen upon the egg has begun,—they opened three thousand eggs. Now, why is it that we have not yet such knowledge of the horse? Because there are not three thousand mares to be sacrificed to study their development; and unless some means are found by which something of the kind can be done, we cannot have the beginning of the history of that one animal; unless, perhaps, with the greater knowledge we now possess and long acquired skill, a smaller number of individuals may suffice; but not until hundreds and hundreds of animals are sacrificed for that purpose, under proper conditions, can we have the first fact concerning their history. And if you find in physiological text-books this subject treated as if it were entirely known, it is simply because the data in reference to the animals, the physiology of which is given in our text-books, are borrowed from the four animals carefully studied by Bischoff, and not from any particular knowledge obtained from the domesticated animals themselves. When, in our human physiology the embryology of the human race is presented, it is largely illustrated by conditions which have been studied from the rabbit, the dog, the guinea-pig and the roebuck. Direct observations are so few that they are hardly worth mentioning. A few cases of suicide have furnished the only information which is on record concerning the first condition of the human being.

And now I propose to show you what an egg is, and then to satisfy you that all animals produce such parts as deserve the name of egg.

A hen's egg, surrounded by its shell, which is calcareous, is lined on the interior by a double membrane. A skin extends over the whole internal surface, and that skin is double; and in one part of the shell it recedes from the shell and leaves an open space, which is the air-chamber of the egg. These are only protections of the egg, and are formed last upon it. In the interior of the egg we have a round ball of yolk which is suspended in the egg by two cords of somewhat harder albumen than that which surrounds the yolk. These two cords keep the yolk so suspended in the egg that whatever position you give the egg, certain parts

always remain uppermost. You may open any number of eggs and you will always find that a little white speck stares you in the face. You may turn the egg as you please, but that little speck will always be uppermost. This is owing to the fact that the yolk is heavier in one portion and lighter in another and that it may swing upon the two strings of albumen by which it is suspended. This speck, called blastoderm by embryologists, is the part from which the young chick is developed when the egg is brought under proper conditions of temperature, etc.

As to the albumen, or white, it is not one mass; it consists of a number of layers; and when you boil an egg so that the whole is hardened, it is easy to see that it peels off in these layers, which are deposited one after another. Now such an egg has a history. It does not begin to be an egg of that size; it does not begin with having a shell; it does not begin with having these membranes within the shell; it does not begin with having the white around the yolk. There is a time when the egg has neither shell, nor these membranes, nor the white, but when the whole egg is yolk; and you may find such eggs in the organ called the ovary, in which the eggs are produced. If we look carefully at the ovary of the hen, we find that it contains a variety of eggs. It has eggs which have attained to their full size—they are about the size of a small walnut—it may contain a certain number of these—but by the side of these large yolks there are smaller yolks of various dimensions, and if you will examine minutely, you will soon see that there are those, which, at the distance of a few feet, you could not see at all, even if I represented them magnified a great many times; and you gradually, by learning to watch more and more closely, detect among this mass of eggs which are readily visible, others which are less and less distinct to the eye; and if you take a magnifying glass, you find that there are others which had escaped your eye when you had no magnifying power to help you; and, if you use higher and higher power, you begin to find that there are more of these most minute eggs, which loom up to your eye in proportion as you use a higher power of the microscope. It is like the starry heavens, where you have stars of first, second, fourth and tenth magnitude, some of which are visible to the naked eye, and others only through the telescopes of our observatories. Yet all these small specks in the ovary, invisible to the naked eye, are *bona fide* eggs. As soon

as one of the full-grown yolks drops, to be taken up by the fallopian tubes and carried through the oviduct, there to be surrounded by albumen, and then by a shell,—another grows larger, and when all those which are at any moment of full size have been laid, they are followed by another crop, and crop after crop comes to the surface of the organ, ready to be laid in succession. If you watch their growth, it is easy to see that each one passes into the condition of the eggs higher in size by a process of increase which is similar to the process by which a young animal grows to acquire the dimensions of an adult. Nobody now doubts that these small granules scattered through the ovary are really eggs in their incipient condition.

How do they look when examined under the microscope,—say under a microscope magnifying two hundred and fifty times the diameter,—an egg, therefore, which could not be seen by any human eye? You magnify it, as I have said, two hundred and fifty times, and you will see that that egg is a sphere, which you may, with the microscope, magnify to look as large as a full-grown yolk. It is then perfectly transparent, as if it were full of a uniform fluid, like water; but at some places on the side it has a little vesicle, a little bag, which is also transparent, and may only be seen under skilful management; in this again there is still another microscopic body which appears like a small dot. Now you examine an egg a little larger than that, and you will perceive that in it the fluid mass is obscured slightly by small dots. If you apply the highest powers of the microscope to these dots, you very soon find that they are not solid granules, but that they are hollow vesicles which, in their turn, produce other granules within themselves, so that the growth of an egg is in fact the enlargement of little granule-like masses of animal substance, which are transformed into bag-like bodies within which the same process is repeated over and over again. As the whole egg grows larger, these little granules burst and scatter their contents into the surrounding fluid; and the egg, from perfectly white, becomes slightly tinged with yellow, and finally grows more and more opaque; and, when the yolk has acquired its full size and is ready to drop, it is really an opaque mass, but consisting throughout of these minute granules.

Now let us take the ovary of the rabbit, the guinea-pig, or any other quadruped, and examine its contents, and we see eggs ex-

actly like these young eggs of the hen; so similar to them, that the most skilful observer is incapable of distinguishing the one from the other,—the egg of a rabbit from that of a hen. Of course they do not remain in that condition. There is this peculiarity: that the egg of a quadruped remains small, and while retaining these small dimensions undergoes of itself changes by which the germ is developed in time: while, on the contrary, the egg of a bird grows large; even before it has its shell, its yolk becomes very large, and it is surrounded by those auxiliary means of protection necessary for an egg which is to be cast before the germ is formed; while the fecundated eggs of mammalia are not cast, and the young undergo their development in the egg while the latter is still retained by the parent. And so it has been proved by Baer, that there is no difference whatsoever between so-called viviparous and oviparous animals, but that all produce eggs which have the same identical structure, and which differ from one another only by their various capacities, by the various proportions which they attain, and by the various ways in which the germ is developed in them.

One more word to satisfy you that this is the case in all animals. Eggs of the larger birds have been observed as I have said, and it needs not to be repeated that in every species in which the observation has been carried on, it has been found that the ovarian egg,—that is, the egg prior to its being laid,—has the small dimensions and the peculiar structure characteristic of all ovarian eggs in their earliest condition. This is also the case with reptiles. Our little turtles lay eggs of considerable dimensions in comparison with their size; but examine their ovary, and you will find that there are contained in that organ eggs of all possible dimensions, as in the bird, and that when young these eggs do not differ from the egg of the quadruped. And so it is with the fish, whatever be the kind of fish. I have examined many sharks and skates, as well as many of our salmon and trout and our various kinds of suckers and codfish, and I know that all these different kinds of fish produce similar ovarian eggs. Some of them lay them early, and lay eggs which are at once recognized as eggs, and others retain their eggs until the young are fully developed and they bring forth then, like the quadruped, living young; so that they exhibit within the limits of one and the same class differences similar to those which we observe among

different classes in the higher animals. And if we pass from the class of fishes to the lower types of the animal kingdom,—to insects, for instance, crustacea, and worms,—we find everywhere the same process. Even the parasitic intestinal worms are now known to be produced by eggs, and eggs which are transferred by various processes from one animal to another, sometimes with their food or drink, at other times by boring into the body of their host, thus remaining parasites in succeeding generations. The same thing has been observed among the various kinds of mollusks,—the cuttlefish and periwinkles, the oysters, mussels, etc., for all these produce eggs; and when the eggs are examined, at the proper time, and in a proper manner, they exhibit exactly the same structure as those of the higher classes; and we may go down to the very lowest classes of the animal kingdom—the seaurchins, the starfish, the jellyfish, or even the corals or polypes, and there again eggs are found, and eggs which in no way differ from those of the higher animals.

From such statements, which cover now such extensive ground, it might be inferred that to know one is equal to knowing all. By no means; for enough has already been done to show us that every one has its peculiarities, every one has its own mode of development, and in every one there are peculiar processes which make the generalization only true in the most comprehensive form of expression, and no longer true in the details of the farther development. So that all our knowledge of the process of reproduction in one species of animals may not give us an answer when we would inquire into the corresponding process in another animal. Thus you see the necessity of repeating for those animals, the breeding of which we would desire to influence, all those observations which have been made upon a few.

I should like presently to make some remarks as to the kind of training necessary for this, that you may not imagine that the first enthusiast can go to work and do it. It requires a long training to be prepared to look at an egg, to be prepared to see how it grows; but before I make any such remarks, I would say a few words more concerning the formation of the germ, so that you may see what an interesting field of observation is now open to the student; *open*, not yet *cultivated;* by no means cultivated to the extent desirable in order to make the knowledge in any way useful in practical life. There is that condition necessary to

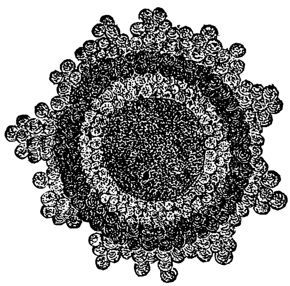
all knowledge, that it should be acquired, not only in its general features, in order to be useful, but that it should be brought to a point where it shall be really applicable to any practical purpose; and a great deal of the difficulty in scientific investigation arises from the fact, that while it is easy to study, to a certain extent, it is not always easy to carry our knowledge to the point where its application becomes easy or even practicable. And I would say, to exonerate science from its failure to make itself more generally popular and practical, that the mental qualities required for investigation are not the same as the qualities required for practical application. You know too much of practical life to need to be told that the importers who bring to your manufacturing establishments the raw materials are not those who make the cloth for your clothes; or that those who import the raw materials with which all the various manufactures are produced are not likely to be themselves manufacturers; and the ability of the one excludes very often the ability of the other. In scientific matters this is perhaps more extensively the case than in practical pursuits, so that a class of men must be educated who will take up knowledge where the scientific man leaves it, and carry it where the man of business, or the practical man, requires it. I could mention many a case in which scientific men have injured themselves in their attempts to derive profits from their scientific work or to apply their knowledge to practical purposes. That will happen again and again when scientific men rashly enter the arena of practical life. You must allow them to work in the field for which they were prepared, and accept from them what they can give. I claim that as due to science, and I think the sooner the community understands it the sooner will all have the benefit of what science can produce, and cease to ask the impossible from scientific men.

In this first presentation of the subject of embryology I shall not be able to give the whole history of the formation of a new being, but only so much of it as will satisfy you that our higher animals produce eggs like birds and the lower classes; but with this essential difference, that in mammalia the fecundated egg is not cast or laid, but undergoes all its changes within the maternal body until the living young is dropped. Here are several figures of ovarian eggs of the dog, rabbit and human female, which may easily be compared with the eggs seen in the ovary of a hen. Figures 154, 155, 156, 157, 158, 159, 160 and 161 are such ovarian eggs.

Figures 154, 155, 156, 157, 158, 159 and 160 show that the eggs of different mammalia, such as rabbits and dogs, resemble one another as much as the eggs of different species of birds belonging to different orders of this class.

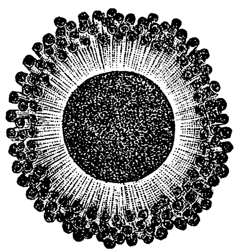
The formation of a germ in the egg begins by a very peculiar process, called "segmentation." It is unquestionably a manifestation of the internal life of the egg,—for an egg must be

Fig. 154.



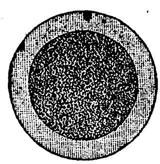
Ovarian egg of dog. Copied from Bischoff's embryology of the dog. Magnified 100 diameters.

Fig. 155.



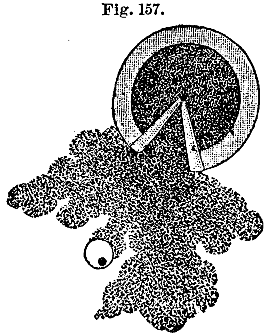
Another ovarian egg of dog, from a female in heat. Copied from Bischoff. Magnified 100 times.

Fig. 156.



Ovarian egg of dog, freed of the cells which surround the zona pellucida in figs. 154 and 155. Copied from Bischoff. Magnified 100 diameters.

Fig. 157.

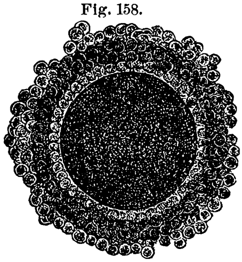


The same ovarian egg as that represented in fig. 156, cut open with a sharp needle. The mass escaping is *yolk*, with the transparent *germinative vesicle*, in which the *germinative dot* is visible. Copied from Bischoff. Magnified 100 times.

considered as a living body. Segmentation consists in this. Supposing we have here the egg of a dog, copied from Bischoff (fig. 162): the egg divides itself spontaneously into two halves (fig. 163), which are entirely independent of one another, and only retained together by the common envelope of the yolk. After that, each half divides itself into two halves again, so that the yolk

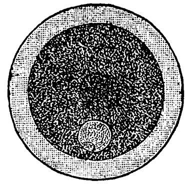
consists now of four masses of equal dimensions (fig. 164); and so the process goes on. Each quarter of the yolk divides itself again into halves, so that we next have eight such bodies (fig. 165); first, irregular in shape, but very soon assuming the form of spheres, which fill the cavity of the yolk-membrane. Eight balls, as it were, resulting by spontaneous division in the formation of a mulberry-like body as is represented in fig. 165; and this is divided again, until the eight have become sixteen (figs. 166 and 167), the sixteen thirty-two (fig. 168), the thirty-two sixty-four, and so on until the whole of that mass is separated into little granules which are about as small as the primitive cells of which the yolk consisted (fig 169). We have then a

Fig. 158.



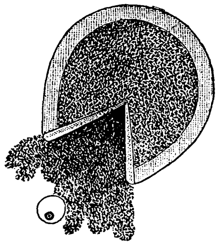
Ovarian egg of rabbit. Copied from Bischoff's embryology of the rabbit. Magnified 125 diameters.

Fig. 159.



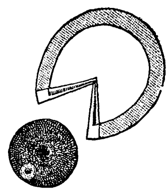
Ovarian egg of rabbit, freed of the cells which surround the zona pellucida in fig. 158. Copied from Bischoff. Magnified 125 times. The *germinative vesicle* shines through the *yolk* as a light spot.

Fig. 160.



The same ovarian egg of the rabbit as in fig. 159, opened with a needle. The yolk, with the germinative vesicle and dot are flowing out. Copied from Bischoff. Magnified 125 times.

Fig. 161.



Ovarian egg of a human female, cut open. The yolk has escaped whole, and in it the germinative vesicle and germinative dot are seen as a lighter spot. Copied from Bischoff. Magnified 100 times. The resemblance to the eggs of the rabbit and dog, represented in figs. 157 and 160, is very striking.

Fig. 162.

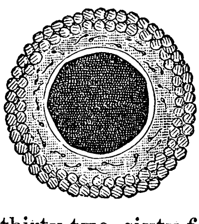
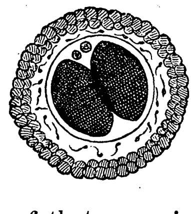


Fig. 163.



well-kneaded yolk-mass very similar to what the primitive cell was, only that, instead of simple yolk-cells, it now consists of an innumerable quantity of little spheres which have resulted from the spontaneous division of the whole into successively multiplied halves. There is, however, this difference,—that on one side of the egg there is, when this process is completed, a larger number

Fig. 164.

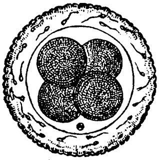
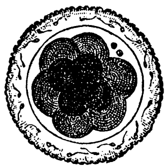


Fig. 165.



of these small balls or globules than on the other, and they are more whitish. The difference arises from the fact that the balls multiply more on one side than on the other. In quadrupeds this process of self-division pervades the whole yolk, so that in the centre and on the periphery, and on all sides, it is evenly divided, except that on one side the spheres are somewhat smaller and also somewhat more whitish. In the yolk of a hen

Fig. 166.

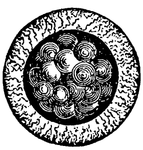


Fig. 167.

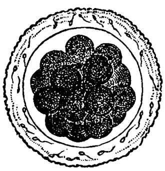
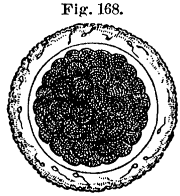
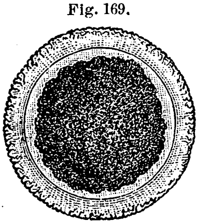


Fig. 168.



the process is widely different, and has been known only for a comparatively short time, for in the hen the process also takes place before the egg is laid. In order to examine it, therefore,

Fig. 169.



a hen must be killed and the egg must be observed during its passage through the oviduct, when on the surface of the yolk, and on the surface only, furrows are marked as if made with a nail. These furrows are multiplied crosswise, and then crosswise again, and this process is repeated until the whole surface is changed into these same globular bodies, already noticed in the rabbit and dog, but which in the hen extend only over a small part of the surface of the yolk. Now this small part of the surface of the yolk is that white speck which is seen at once when you open the shell of an egg; and from it the chicken is developed. In fishes, there is still another process. Suppose we take the salmon. The first segmentation of the yolk consists in halving

and quartering, and then the process of self-division goes on only in one-half, viz., in the upper half of the yolk, the lower half undergoing no change, so that you have at first only two spheres, one below and one above, then two in the upper part, then four in the upper part, then eight in the upper part, then sixteen in the upper part, the lower part remaining in its primitive condition, and the whole upper part finally being transformed into a body similar to what we have as a whole in the mammal, resting as it were on a cup of unaltered, unchanged yolk in the lower part. In the fish, it is this mulberry-like, segmented portion of the yolk which is changed into the germ, while the other half takes no part in the formation of the germ, but only feeds it, being in fact absorbed into it. The egg is actually a live being, only it is a live being which struggles into its structure by its own activity; and in the formation of the organs it afterward possesses, the process of growth is not one of enlargement simply, but involves such changes as to transform a uniform mass into a variety of systems built of different tissues and endowed with special functions. In the chicken, two parallel swellings first arise along the middle line of the back, leaving a shallow furrow between themselves; and the white disk, spoken of above as a white speck, enlarges and spreads so as to cover the whole surface of the yolk visible from above. If you look at this furrow in a section it will be something like an arch, open above. Gradually this furrow grows wider at one end, with indentations right and left, and then the margins of the disk spread, and, folding downward, enclose more and more of the yolk, and the sides of the furrow thicken, so that represented in profile it will be no longer a shallow furrow, but something like a channel or tube.

At this stage the whole mass has still about the same consistency everywhere. It is like soft jelly and a little pulpy, but presently the two edges of the furrow come more closely together, and finally touch. Meanwhile the margins of the new being rise in a fold and enclose the central parts, forming a sac around the germ, known as the amnios. The natural result of the closing of the upturned edges of the germ is the formation of a cavity, enclosed between these edges. That cavity now fills with a transparent fluid, and as it fills there appears something a little more substantial upon its sides and below it; the walls protecting the cavity become less transparent or even slightly opaque; then the cavity

widens sidewise on its anterior part, and rises a little from the rest. In one word, this cavity forms the channel for the spinal marrow, and its front part the cavity for the brain, and the walls grow to be flesh and bone to form the dorsal spine. The upper part represents the axis of the skeleton, with the surrounding soft parts: the lateral parts form the ribs with their fleshy covering, and, the animal thus closing over the yolk, we have the abdominal cavity. Now, it requires a little more enlargement, a little more change into different substances, to complete the formation of the new being. The gelatinous substance outside the main axis is changed into a fibrous structure, which is muscle. The little opaque bodies in the axis and upon its sides absorb some earthy material contained in the primitive substance from which they have arisen, and thus bone is formed. The fluid in the upper cavity becomes a little more granular and more solid, and it is the brain and spinal marrow. The yolk is absorbed during the process of growth, but the wall within which it is contained is elongated and enlarged, and in consequence of farther changes in the substance of that part of the yolk which is in immediate contact with the body-walls, the alimentary cavity is formed. You have, in fact, all the organs of the animal growing in the same way, by successive transformations of the homogeneous mass into all the various tissues and organs which build up the animal in its perfect condition.

From the time the chick has reached the condition in which all its organs are fairly sketched, it simply grows larger and larger, and finally breaks through the shell. The skin has already become distinct from the muscles; the feathers begin to be formed, and all those parts with which you are familiar may readily be distinguished. You see now by what complicated process (the details of which I have considerably abridged) this is brought about.

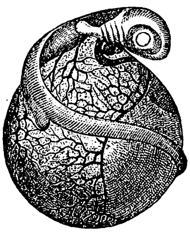
I have given you but a meagre outline of the changes which take place in the formation of quadrupeds, birds, reptiles, and fishes, though this may be sufficient to show that these processes must be studied in every animal independently.

The figures on the following page, representing a fish in the egg, show at once how different the growth of these animals is from that of the mammalia and birds. Here we have no amnios; the young fish remains free upon the surface of the yolk. The structure of the body, however, and the circulation of the blood upon the yolk, are strikingly similar to those of the dog, the

chicken, or the little turtle. Compare in this respect the figures of D'Alton with those of Bischoff and my own in the embryology of our terrapene.

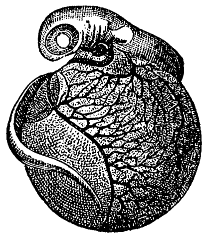
Now, what are the conditions necessary for making these observations? A man must be practised, and not only practised, but fully skilled in the use of the microscope. He must know the structure of the animal in its adult condition so accurately, and so completely, that every difference in the structure of the younger animal will at once strike his eye. He must be able to make these comparisons without having specimens before him for comparison;

Fig. 170.



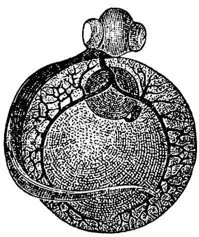
Young Blenny, copied from Rathke's Embryology of the *Zoarces viviparus*. Magnified. Seen in profile from the right side.

Fig. 171.



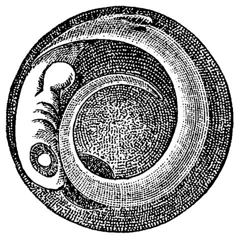
The same as fig. 170, seen in profile from the left side.

Fig. 172.



The same as figs. 170 and 171, seen in front.

Fig. 173.



The same as figs. 170, 171 and 172 before the egg-shell has burst.

he must have appropriated that knowledge to himself so completely that he may weigh the changes going on in the substance of the germ, merely by the eye, and ascertain every change in so accurate a manner that he may record the facts in their true connection. And more than that, he must be able to prepare the conditions in which these germs will not be altered by being brought under the microscope. Try to bring an embryo, a young chick, in that early stage of growth, as you see it after a few days' incubation, under the microscope, and you are likely to find

that you have reduced it to a shapeless mass. These objects cannot be handled like a piece of wood. They must be treated with a degree of delicacy which makes it impossible, for instance, for an observer to use any stimulant, even such as coffee and tea, or to eat heartily, or to exercise in any degree which may accelerate the pulse; otherwise his eye will be constantly thrown out of focus. Unless a man has himself under control to that extent, he cannot begin to make good observations. Not only must he have the knowledge necessary, not only must he have the practice necessary, not only must he have the instruments necessary—he must have his own organization so completely under control that he brings himself into that living relation with the object of his observations which alone makes it possible that they shall be accurate. It is not everybody who is willing or able to do this; and then he must carry on his observations by day and night, as the embryo is growing unceasingly, and unless he does continue his observations uninterruptedly, he may miss the most important steps in the progress of growth. Now before you find a man qualified to be an observer, you may have to wait a long while. It was just so during our late war. We did not find the generals who knew how to command, the day of the first battle. It requires years to find a man capable of leading two hundred thousand men. In matters of scientific progress we need a great many students, and large schools, from which to pick out the man who is capable of making new discoveries, or simply accurate investigations; and have we these schools now? Is the number of our scientific students proportionate to the intellectual capacity of the nation? By no means; and until our system of popular education is radically changed, or so far changed, at least, that in all our schools instruction is given in those branches of science which train observers, you may not even have the knowledge necessary to carry on your practical pursuits, and still less the chances of making any real progress. These results can only be brought about by introducing into our schools that sort of instruction which prepares students to become observers, or at least, which gives the teacher an opportunity of ascertaining whether any of his pupils may be educated into an observer or not. Such schools we have not, such teachers we have not, or very few of them—half a dozen in Massachusetts is the sum-total of men qualified to teach in that way; and the schools in which they may teach, the apparatus necessary for that

instruction, we have not. We have to build them up, and we shall not have them before the community understands what are the conditions necessary for the acquisition of new knowledge which may improve the conditions of our success in the practical affairs of a civilized community.

You may ask what text-books you shall take to begin with. There are none that I would recommend. You cannot use the present text-books, for most of them are manufactured by people who know nothing or precious little of the subject about which they write. They are mere compilations, made for the market, by men who have no sort of knowledge of what should be the substance of a text-book; and, what is worse than that, our schools are crowded with so large a number of pupils that the teachers, even the very best of them, have to resort to all sorts of devices in order to keep alive. Instead of teaching, that is, instead of giving out of their knowledge and their substance something by which they can vivify the intellect of their pupils, they are forced by the pressure of numbers to direct their pupils to commit to memory some superannuated book, and to make them recite things not worth knowing. So there we must begin. We must begin by relieving the teacher from a task to which no human being is equal; for it is impossible for any one person to teach eighty pupils well, in one and the same room, at the same time, and to teach every branch of human knowledge in close succession. It is physically impossible. It is past endurance; and all those who have tried to do this kind of work, honestly and faithfully, have paid for the effort with the loss of health. And then there is another point. In order to get men capable of performing the difficult task of teaching, you must give greater inducements to able intellects to devote themselves to the task. The teacher's profession must not be the least remunerative of any profession in the community, as at present it is. Only those who by nature cannot help being teachers go into it, and their willingness to teach is misused by the community by giving them a pittance for their existence. So one more thing is needed: you must organize normal schools to educate teachers of natural history and science generally. You must not only determine that you will introduce these branches of knowledge into your schools, but you must prepare teachers for the task.